Effect of Local Land use on Benthic Macroinvertebrates in Headwater Streams, Western Thailand

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Abstracts: Benthic macroinvertebrates were investigated at fifteen sites in each season within the headwater streams at Thong Pha Phum District, from December 2001 to May 2002. Macroinvertebrates were collected using a Surber sampler and selected physico-chemical variables were measured *in situ*. Water quality analysis showed that sampling sites were clustered into two groups: (i) the forested areas and sites far away from agriculture (ii) the agricultural and residential areas. The latter group had high EC and TDS. The benthic community corresponded to water quality and land use and sampling sites could be discriminated into three groups: (i) the forested site (ii) the agricultural sites, and (iii) the residential sites. The agricultural sites had lower taxa richness of sensitive groups (EPT), but the percentage of tolerant chironomids was higher. Multivariate analysis showed more clearly illuminated the change of assemblage along the environmental change gradient than did species richness and biotic indices.

Key words: headwater streams, benthic macroinvertebrates, land use

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Introduction

The consequences of drainage-basin degradation and deforestation are evident throughout the tropical Asian region and include increased runoff, sedimentation, and flash floods. Pollution from agricultural areas and non-point sources is largely uncontrolled, and domestic wastewater treatment is limited (Dudgeon, 2000). In Thailand, agricultural land use is currently the leading problem, being a contributing factor for 57 % of soil erosion (Office of Environmental Policy and Planning, 1997).

Sediment, nutrients and pesticides are the most common pollutants from agriculture. Sedimentation represents the largest volume of aquatic contaminant. Many studies have documented that sediment deposition adversely affects aquatic habitats and biota (Cooper, 1993; Wood and Armitage, 1997; Nerbonne and Vondracek, 2001). Several studies have indicated that land use is an important factor controlling the structure of the aquatic communities (Lenat and Crawford, 1994; Delong and Brusven, 1998; Lammert and Allan, 1999; Paul and Meyer, 2001).

Benthic macroinvertebrates have an important influence on nutrient cycles, primary productivity, decomposition and translocation of material (Wallace and Webster, 1996). They are the most commonly used group of organisms in biological monitoring (Rosenberg and Resh, 1993). Many studies indicated that benthic macroinvertebrates have potential use for water quality assessment in Thailand (Mustow, 1997; Sangpradub et al., 1998). In the future, studies on the macroinvertebrate fauna seems to be necessary for biological monitoring and assessment of freshwater ecosystems in Thailand.

The aim of this study was to investigate the correlation between land use and the benthic macroinvertebrate assemblage in headwater streams, Western Thailand.

Methodology

1. *Study area*

The study area lies within the Maeklong River Basin, located in Western Thailand. Sampling sites were chosen at the upstream part of Khoa Lam reservoir at Huai Khayeng Settlement, Thong Pha Phum District, Kanchanaburi Province. Fifteen sampling sites were selected, eleven sites from Huai Khayeng (K01-K11) and four sites from Huai Team (T01-T04) streams (Fig. 1). All sampling sites were surrounded by different land uses (forested, agricultural and residential). Physical characteristics of each site are summarized in Table1.

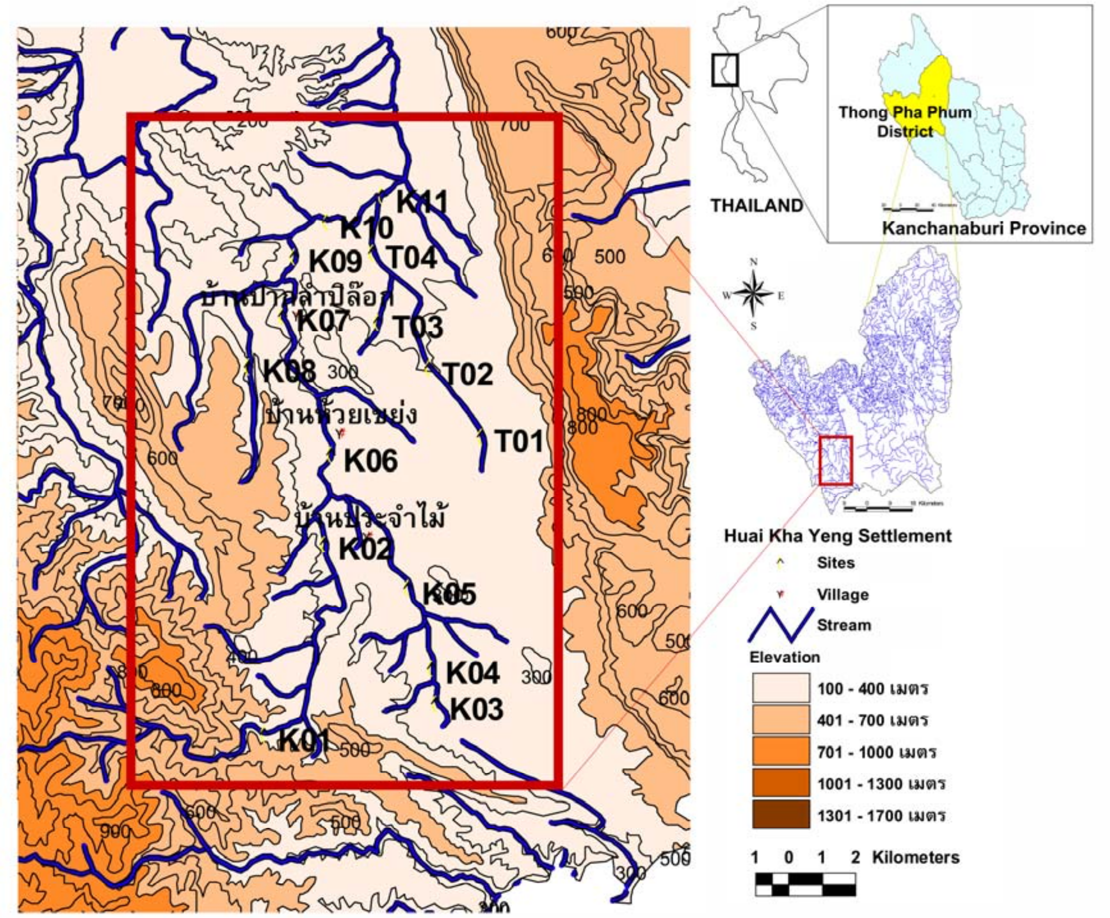

Figure 1. Location of sampling sites in Huai Khayeng and Huai Team streams, Kanchanaburi Province, Thailand.

2. *Sampling and Data Analysis*

Benthic macroinvertebrates were collected using a Surber sampler and selected physio-chemical variables (velocity, water and air temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH and dissolved oxygen) were measured *in situ*. Six replicates of benthos and water samples were taken at each of fifteen sites along two streams during three seasons (cold - December 2001, hot - February 2002, and rainy - May 2002). All macroinvertebrates were preserved in 70% ethyl alcohol. Macroinvertebrates were sorted and identified to the lowest practical taxonomic level in the laboratory.

Habitat structure was assessed on the sampling reach using methods based on the United State Environmental Protection Agency (U.S. EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al., 1999).

Data analyses used both univariate and multivariate techniques. Multivariate analyses used the software PATN (Bellin, 1995) consisting of agglomerative hierarchical clustering (UPGMA, **U**nweighted **P**air **G**roup **M**ean **A**verage) and ordination (SSH, **S**emi-**S**trong **H**ybrid Multidimensional Scaling).

Results and Discussion

1. *Water Quality*

All ninety water samples from 15 sites over three seasons were classified using the UPGMA and SSH. The results of SSH is shown in Fig. 2. Four groups were clearly recognized. Group I consists of all of the samples from sites K01-K02. Group II comprises all of the samples from sites K03-K04. Group III consists of all samples from sites K05, K08 and T01-T04. Group IV cover all of the samples from sites K06, K07, K09, K10 and K11. EC and TDS parameters were significantly correlated with both axes and Group III, for which the concentration was relatively high. The results revealed that water quality of both streams were acceptable for aquatic organisms (Pollution Control Department, 1997). Measured dissolved oxygen concentrations were never less than 4 mg/l at any site. However, conductivity and total dissolved solids were greatest in the

Table 1. Physical characteristics of fifteen sampling sites.

Site Code	Latitude	Longitude	Elevation (m)	Stream Order	Location	Substrate Composition	Land use
K01	14°33′01.1″N	98°34′08.9″E	300	3	Ban Pudsadu Klang	boulder 15% cobble 45% pebble 10% gravel 10% sand 10%	forest
K02	14°35′06.0″N	98°35′07.1″E	210	3	Ban Pra Chum Mai	cobble 60% pebble 15% gravel 15% sand 10%	agriculture/residential
K03	14°33′17.8″N	98°35′48.8″E	270	1	Ban Rai Pa	silt 90% litter 10%	agriculture
K04	14°33′18.0″N	98°35′51.8″E	270	1	Ban Rai Pa	pebble 10% gravel 50% sand 40%	agriculture
K05	14°34′39.8″N	98°35′52.9″E	240	3	Ban Rai Pa	silt 80% gravel 10% litter 10%	agriculture
K06	14°36′00.1″N	98°34′41.6″E	210	4	Ban Huai Khayeng	boulder 80% cobble 10% sand 10%	agriculture/residential
K07	14°37′54.3″N	98°34′17.4″E	180	4	Ban Pak Lum Pilock	boulder 50% cobble 10% gravel 20% sand 20%	residential
K08	14°37′50.3″N	98°33′41.7″E	210	1	Ban Pak Lum Pilock	cobble 20% gravel 40% sand 40%	agriculture
K09	14°38′54.6″N	98°34′42.0″E	150	4	Ban Tao Tan	cobble 30% pebble 50% gravel 15% sand 5%cobble 40% pebble 10% gravel 30% sand 20%	residential
K10	14°38′52.2″N	98°35′07.3″E	150	4	Ban Tao Tan	cobble 30% pebble 50% gravel 15% sand 5%	residential
K11	14°39′00.6″N	98°35′14.6″E	150	4	Ban Tao Tan	cobble 80% pebble 10% gravel 5% sand 5%	residential
T01	14°37′32.9″N	98°35′54.4″E	210	1	Ban Ta Ma Duea	silt 90% litter 10%	agriculture
T02	14°37′47.4″N	98°35′47.2″E	180	1	Ban Ta Ma Duea	silt 90% litter 10%	agriculture/residential
T03	14°37′55.4″N	98°36′01.0″E	180	1	Ban Ta Ma Duea	silt 90% litter 10%	agriculture
T04	14°38′31.0″N	98°35′26.0″E	150	2	Ban Ta Ma Duea	boulder 70% cobble 10% gravel 10% litter 10%	agriculture

agricultural stream. This may reflect the influence of the agricultural activity (Lenat and Crawford, 1994).

2. *Habitat assessment*

Habitat assessment based on visual observation can separate the forest site (K01) from the other sites, while agricultural and residential sites did not show a large between site difference in habitat structure. For this study, visual estimates of physical habitat indicated that the forest site had good riparian zones and vegetative protection, whereas riparian buffers and bank stability of the agricultural and residential site test sites were scarce. The ability to accurately assess the quality of the physical habitat structure using a visual-based approach depends on several factors. Thus, the parameters selected to represent the various features of habitat structure need to be relevant and clearly defined, and the investigators need to be experienced in or adequately trained for stream assessments (Barbour et al., 1999).

3. *Benthic Macroinvertebrates*

i) Fauna

Fifteen orders, 96 families, 218 genera and approximately 223 species of benthic macroinvertebrates were found from the fifteen sites during the survey. The fauna was dominated by the immature aquatic insects, the taxa collected also included members of Collembola, Decapoda, Mollusca and Oligochaeta. Ephemeroptera was the most abundant (24%), followed by Coleoptera (20%), Trichoptera (16%) and Diptera (15%), respectively. The most common families were: Elmidae (Coleoptera), Chironomidae (Diptera), Leptophlebiidae (Ephemeroptera), Gerridae (Hemiptera), Gomphidae (Odonata), Perlidae (Plecoptera) and Hydropsychidae (Trichoptera).

Genera such as *Cryptoperla* (Plecoptera: Peltoperlidae), *Epeorus* (Ephemeroptera: Heptageniidae), *Ephoron* (Ephemeroptera: Polymitarcyidae), *Limnocentropus* (Trichoptera: Limnocentropodidae) and *Oestropsyche* (Trichoptera: Hydropsychidae) characterized streams with riparian forests, whereas genera such as *Choroterpides* (Ephemeroptera: Leptophlebiidae), *Cheumatopsyche*

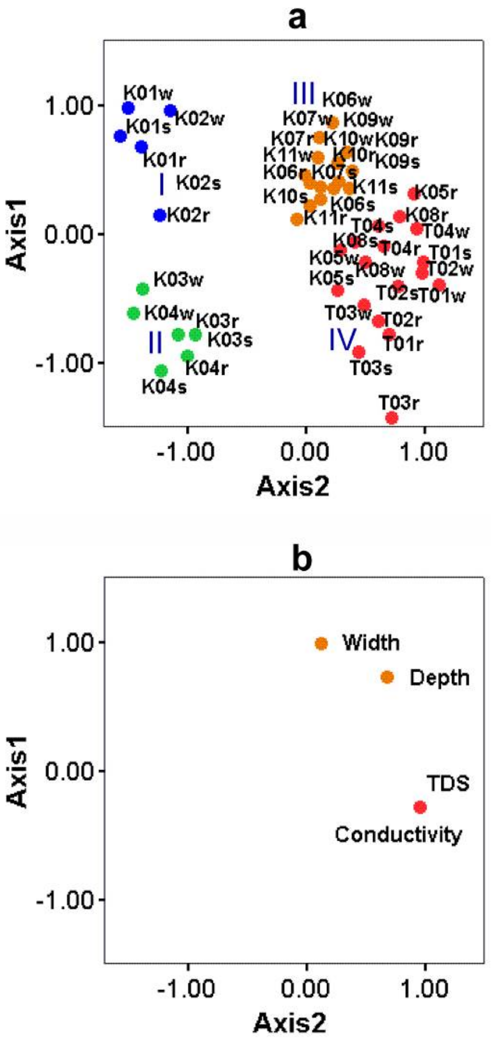

Figure 2. Results of multivariate ordination on water quality data (stress = 0.102). a) SSH ordination of sampling sites based on the physico-chemical data showing four groups. b) Water parameters strongly correlate to ordination space.

(Trichoptera: Hydropsychidae), and *Baetis* (Ephemeroptera: Baetidae) characterized streams with agricultural and residential areas. Ephemeroptera were very abundant in this study area. They were often found in mid stream, which provided substratum, food and oxygen (Brittain, 1982). Coleopterans and trichopterans had the greatest taxon richness; they are diverse in tropical Asian streams (Dudgeon, 1999).

ii) Multivariate analyses

All benthos data sets were classified using clustering and ordination methods. SSH ordination is shown in Fig. 3. Cluster analysis revealed that all samples from the forested sites (K01) were more clearly separated from the other sites than did the ordination method. All sampling sites were clustered into three groups: Group I (the forested site), Group II (residential sites) and Group III (agricultural sites). These three groups corresponded to water quality groups and land use patterns. K01 separated into a single cluster; this indicated that macroinvertebrate assemblage composition remained relatively constant from the headwater. The water quality data from K01 was similar to those of K02 but the benthos data showed that the benthic assemblage of K01 was more unique and diverse than that of K02. This clearly indicates that K01 could act as the reference site. Fig. 3b shows the benthic species that strongly correlated with ordination space. Most benthic species occupied fast-flowing areas. They correlate with Group I and II. The common impacts of agriculture on drainage basins include sedimentation, nutrient enrichment and the presence of pesticides

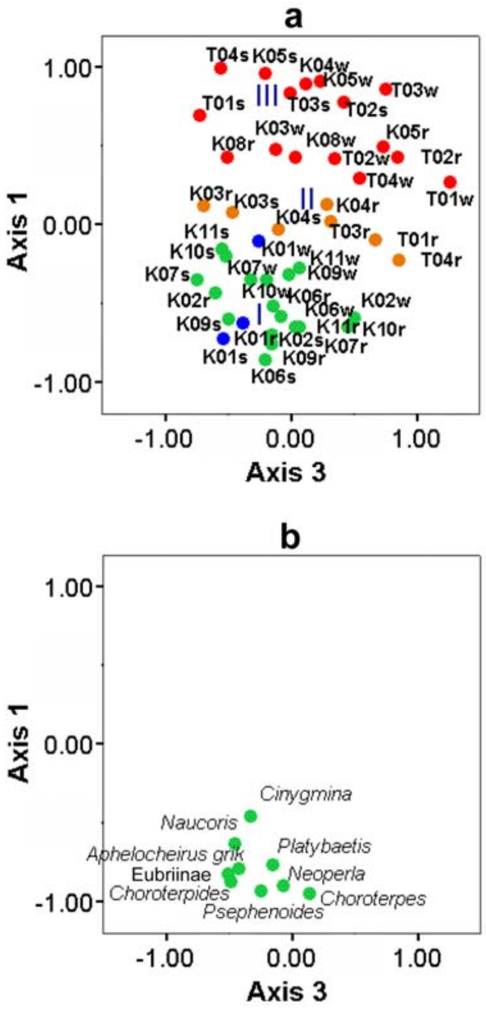

Figure 3. Results of multivariate ordination on benthic macroinvertebrate data (stress = 0.180). a) SSH ordination of sampling sites based on benthic data showing three groups. b) Benthic species strongly correlate with ordination space.

Table 2. Pearson correlation coefficients for relations between macroinvertebrate metrics and water quality (n=263).

Macroinvertebrates metrics	Water Quality				
	Velocity (m/sec)	EC (μs/cm)	TDS (ppm)	pH	DO (mg/l)
No. Total taxa	-0.052	-0.148*	-0.148*	-0.030	0.299**
No. Ephemeroptera taxa	0.375**	-0.315**	-0.315**	0.016	0.173**
No. Plecoptera taxa	0.376**	-0.418**	-0.418**	-0.252**	0.165**
No. Trichoptera taxa	0.238**	-0.422**	-0.422**	-0.0.32	0.434**
No. EPT taxa	0.038	-0.399**	-0.400**	0.107	0.506**
% Ephemeroptera	0.001	-0.009	-0.011	0.128*	0.327**
% Plecoptera	0.420**	-0.326**	-0.326**	-0.265**	0.173**
% Trichoptera	0.098	-0.155**	-0.155**	0.009	0.027
% EPT	0.041	-0.311**	-0.312**	-0.61	0.416**
Pong Biotic Index	0.249**	-0.410**	-0.410**	0.032	0.392**
% Diptera	0.166**	0.112	0.112	0.074	-0.192**
% Chironomidae	-0.254**	0.309**	0.311**	0.017	-0.372**

**P*<0.05, ** *P*<0.01

(Cooper, 1993). All of these factors can result in a decrease in the diversity of macroinvertebrates. In this study, the benthic macroinvertebrate assemblage response was to reduce overall and sensitive taxa. In this study, the use of multivariate approach more clearly illuminated the change of community structure along the environmental change gradient than species richness and biotic indices (Cao et al., 1996).

iii) Benthic Metrics

The macroinvertebrate metric response to increasing perturbation as shown by correlation analysis is summarized in Table 2. Taxa richness and composition of overall and sensitive groups (EPT) were significantly negatively correlated with EC and TDS while tolerant taxa (Chironomidae) were significantly positively correlated. Velocity and dissolved oxygen are positive correlated with sensitive taxa. Number of EPT taxa had the highest correlation to dissolved oxygen (r=0.506).

The agricultural sites (K03, K04, K05, K08, T01-T04) had a lower overall taxa richness than either the residential site or the forest site. They had low taxa richness for the sensitive group (EPT) but high for the tolerant group (Chironomidae) (Fig. 4). This decline in taxa richness is the most common pattern reported by other investigators (Lenat and Crawford, 1994; Delong and Brusven, 1998; Lammert and Allan, 1999). Of all the metrics calculated, the most effective measures, from this study, were taxa richness, EPT taxa richness and percent Chironomidae. These metric responses to perturbation are summarized in Barbour et al. (1999).

Results of this study indicate riparian land use exerted the greatest influence on stream communities. Habitat structure may regulate species diversity at local scales, with complex habitats being normally associated with greater species richness than simple ones (Downes et al., 1998). Patterns of macroinvertebrate distribution could be related to the ability of macroinvertebrate taxa to tolerate environmental conditions associated with agricultural land use. Tree cover in riparian zone appeared to increase EPT, total richness and diversity (Rios and Bailey, 2006). Degraded stream channels had poorly developed riparian habitat. As a result of agricultural impacts, lower allochthonous leaf input, greater periphyton growth, and increased sediment input and water temperature are primarily responsible for changes in high gradient streams (Kedzierski and Smock, 2001).

To successfully protect drainage basin resource including their biota, watershed management should be encouraged. Riparian buffers act as Best Management Practices (BMPs) that reduce sediment and nutrient load from agricultural runoff (Nerbonne and Vondracek, 2001). For this study, it is suggested that, to reduce sedimentation, pesticides and nutrient enrichment in agricultural areas, riparian buffers should be used at the local scale.

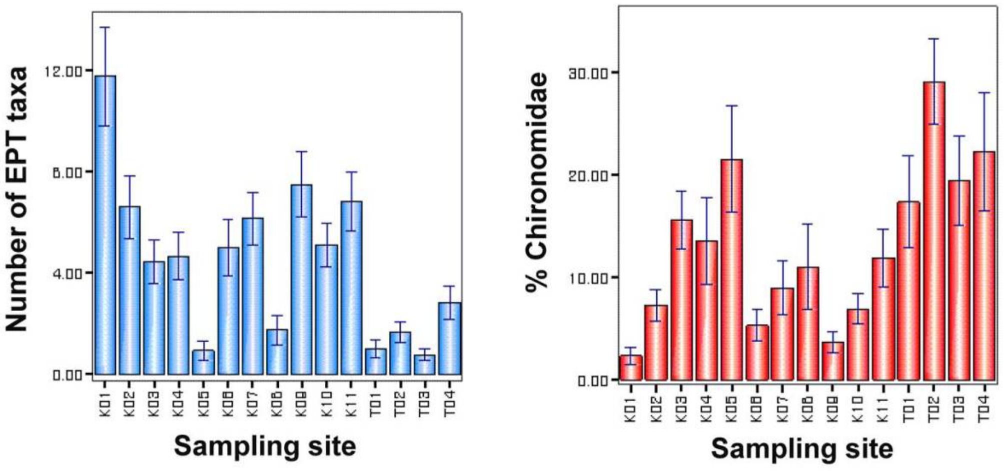

Figure 4. EPT taxa and percentage of Chironomidae metrics that illustrates the classification of the forested site (K01), the residential sites (K02, K06, K07, K09, K10 and K11) and the agricultural sites (K03, K04, K05, K08 and T01-T04).

Acknowledgements

This work was supported by the TRF/BIOTEC Special Program for Biodiversity Research and Training (BRT) and PTT Public Company Limited of Thailand for financial support grant BRT R_145005. We also thank Prof. F. William Beamish for critically reviewing the manuscript.

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